



DISPLAY DEVICE

BACKGROUND OF THE INVENTION

~~1. Field of the Invention~~

~~{0001}~~

The present invention relates to a display device which utilizes an emission of electrons into a vacuum ^{space} ^{formed} which is ^{defined} ^{to produce a display;} between a face substrate and a back substrate, ^{the invention relates} ^{of the type described} and, more particularly, to a display device, which exhibits ~~the~~ excellent characteristics in emitting electrons from an electron source.

~~{0002}~~

~~2. Description of the Related Art~~

As a display device which exhibits ~~the~~ ^a high brightness and ~~the~~ high definition, color cathode ray tubes have been popularly used conventionally. However, along with the recent request for ^{the provision of} ~~the~~ higher quality ~~of~~ images ⁱⁿ ~~of~~ information processing equipment or television broadcasting, the demand for planar displays (panel displays) which are light in weight and require a small space, while exhibiting ~~the~~ ^a high brightness and ~~the~~ high definition, has been increasing.

~~{0003}~~

As typical examples, liquid crystal display devices, plasma display devices and the like have been put into practice. Further, ~~particularly,~~ as display devices which can realize ~~the~~ higher brightness, it is expected that various kinds of

— panel-type display devices, including a display device, which utilizes an emission of electrons from electron sources into a vacuum and is referred to as an electron emission type display device or a field emission type display device, and an organic EL display, which is characterized by low power consumption, will be commercialized.

~~[0004]~~

Among ^{such} panel type display devices, as the above-mentioned field emission type display device, a display device having an electron emission structure, which was ^{proposed} ~~invented~~ by C. A. Spindt et al, a display device having an electron emission structure of a metal-insulator-metal (MIM) type, a display device having an electron emission structure which utilizes an electron emission phenomenon based on a quantum theory tunneling effect (also referred to as "surface conduction type electron source), and a display device which utilizes an electron emission phenomenon having a diamond film, a graphite film and carbon nanotubes and the like, have been known.

~~[0005]~~

Among these panel type display devices, the field emission type display device is formed by laminating and sealing a front panel, which ^{has} ~~forms~~ an anode electrode and a fluorescent material layer ^{formed} on an inner surface thereof, and a back panel, which ^{has} ~~forms~~ electron emission type cathodes and grid electrodes, which constitute ^a ~~a~~ control electrode, ^{formed} on an inner surface thereof ~~with~~ ^{so that}

a distance of not less than 0.5mm, for example, ^{is formed} therebetween, ^{whereby} ~~wherein~~ a sealed space is formed between both panels and the sealed space is evacuated to a pressure lower than ^{the} ~~an~~ ambient atmospheric pressure or to a vacuum.

~~[0006]~~

Recently, the use of carbon nanotubes (CNT) as a field emission type electron source, which constitutes the cathodes of this type of planar display, has been studied. Carbon nanotubes are extremely thin needle-like carbon compound ^{elements} ~~(to~~ ^{speaking} ~~strictly~~, a so-called graphene sheet in which carbon atoms are coupled in a hexagonal shape is formed in a cylindrical shape). A carbon nanotube ~~assembly~~ assembly, which is formed by collecting a large number of carbon nanotubes, is fixed to a cathode electrode. By applying an electric field to the cathode electrode having the carbon nanotubes, it is possible to emit ^{with a} electrons ~~of~~ high density from the carbon nanotubes ^{with} ~~at~~ a high efficiency, whereby it is possible to constitute a flat panel display which is capable of displaying various images of high brightness by exciting a phosphor with these electrons.

~~[0007]~~

^{diagram showing}
Fig. 13 is a schematic ~~view for explaining~~ the basic structure of ^A ~~the~~ field emission type display. ^{device} CNT ^{denotes} ~~is~~ the carbon nanotubes formed on a cathode (cathode electrode) K, A indicates an anode (anode electrode), and a phosphor PH is formed on an inner surface of the anode A. A grid electrode G, which controls

the emission of electrons, is formed in the vicinity of the cathode K, and a voltage V_s is applied between the cathode K and the grid electrode G so ^{that} ~~as to emit~~ ^{are emitted} electrons from the carbon nanotubes CNT. By applying a high voltage E_b between the cathode K and the anode A, the electrons e emitted from the carbon nanotubes CNT are accelerated and the phosphor PH is excited whereby ~~a color~~ ^{giving a color} light L , which is dependent on the composition of the phosphor PH is irradiated. Then, by controlling ^{the} quantity of electrons which are emitted ^{in response to} ~~from~~ the modulation voltage V_s ^{that is supplied} ~~given~~ to the grid electrode G formed in the vicinity of the cathode K, for example, the brightness of the ~~color~~ light L can be controlled.

~~FIG. 14~~

^{showing a} Fig. 14 is a schematic cross-sectional view, ~~for~~ ~~explaining the~~ constitutional example of the field emission type display. In this field emission type display (FED), a back substrate 1 which is formed of a glass plate and a face substrate 2 which is also formed of a glass plate are laminated to each other by way of a frame-like support body 3 which is interposed between both substrates 1, 2. ~~in a state that~~ ^{so as to maintain} The support plate 3 has a height of approximately 1mm, for example, and surrounds a display region ~~for holding~~ ^{the} a given distance between both substrates 1, 2. ^{between the substrates} Further, ~~an~~ inside hermetic space is evacuated and sealed. Cathode lines 13, insulation layers 14 and grid electrodes 15 are formed on an inner surface of the back

substrate 1, while anode electrodes 11 and phosphors 12 are formed on an inner surface of the face substrate 2. Carbon nanotubes of electron sources ^{which are} not shown in the drawing are provided to the cathode lines 13.

~~0009~~

Fig. 15 is a schematic plan view as ^{seen} ~~viewed~~ from the back substrate 1 side of the field emission type display shown in Fig. 14. In the inside of the effective display region AR on the inner surface of the face substrate 2, phosphors R, G, B of three colors are arranged. In this example, respective pixels are defined by partitions 16. In a monochromic display, all phosphors are formed in the same color.

~~0010~~

With respect to the above-mentioned display which uses carbon nanotubes, ^{various publications} ~~literatures~~, such as non-patent literature 1 ("Large Size FED with Carbon Nanotube Emitter" Sashiro Uemura et al., SID 02 DIGEST(2002), pp. 1132-1135), non-patent literature 2 (Fully sealed, high-brightness carbon-nanotube field-emission display"., W.B.Choi et al., Appl.phys.Lett., VOL.75,NO.20, (1999), pp.3129-3131) and the like are known. A field emission type display disclosed in these ^{publications} ~~literatures~~ is configured such that a carbon nanotube paste, which is obtained by forming carbon nanotube powder into a paste, or a carbon nanotube-metal mixture paste, which is formed by mixing carbon nanotube powder and metal powder, is printed on a glass substrate,

and gate electrodes which constitute pull-out electrodes (or control electrodes) and a fluorescent surface which emits light upon incidence of the pulled-out light are arranged on an upper surface of the printed paste.

~~0011~~

Further, ^{examples of} ~~as a prior art related to~~ cathodes which constitute electron emitting portions in this type of panel display, a technique in which the electron emitting portions are constituted of carbon nanotubes formed of cylindrical graphite layers is disclosed in patent literature 1 (Japanese Unexamined Patent Publication Hei1(1999)-162383. Further, patent literature 2 (Japanese Unexamined Patent Publication 2000-36243) discloses a method ^{of} ~~for~~ forming an electron emission portion in which a paste which is formed by mixing bundles, each of which is a mass of carbon nanotubes, into a tacky solution having conductivity is formed into a pattern, and laser beams are irradiated to the pattern thus making the carbon nanotubes emit electrons in a state ^{in which the} ~~that~~ carbon nanotubes are projected from a surface of the pattern.

~~0012~~

Further, patent literature 3 (Japanese Unexamined Patent Publication 2000-90809) discloses a technique ⁱⁿ ~~which forms~~ field emission cathodes ^{are formed} ~~by adhering~~ ^{causing} a bundle of carbon nanotubes ^{to adhere} to a substrate using a conductive resin ~~as a prior art~~. Still further, patent literature 4 (Japanese Unexamined Patent

^{an example}
Publication 2000-251783) discloses ~~the constitution~~ in which
a resistance layer formed of a ruthenium oxide mixture film or
an a-Si thin film is applied to a cathode electrode formed of
a strip-like conductor, and an emitter made of a field emission
material, such as carbon nanotubes, is formed on the resistance
layer. Further, patent literature 5 (Japanese Unexamined
Patent Publication 2001-283716), patent literature 6 (Japanese
Unexamined Patent Publication 2002-157951) and the like
disclose a technique ⁱⁿ which ~~embeds~~ ^{is embedded} a portion of carbon nanotubes
into a metal plating layer formed on a support substrate and
~~uses~~ ^{are used} projecting portions as an emitter.

[0013]

SUMMARY OF THE INVENTION

[0014]

The above-mentioned electron emission type display
device is of a type in which ^a ~~the~~ display is ^{produced} ~~performed~~ by ^{causing} ~~making~~
electrons emitted from ~~the~~ electron sources, pass through
apertures formed in the control electrodes and impinge on the
phosphors which constitute the anodes, so as to ^{excite} ~~make~~ the
phosphors ~~excite~~ and generate light. This display device
provides ^{an} ~~the~~ excellent structure which ^{provides for a} ~~enables the~~ light-
weight ~~and~~ and space-saving planar display ^{which has} ~~while having~~ excellent
characteristics, such as high brightness and high definition.
However, in spite of such ^{an} excellent constitution, the display

device still has ^{problems} ~~tasks~~ to be solved which will be described later. That is, in ^a ~~the~~ flat panel display such as the above-mentioned FED or the like, ^{there are} ~~the~~ positions where ^{the} ~~electron~~ source does not perform ~~the~~ electron emission ~~are present~~ in spots on some portions of a surface of an electron source, and, hence, the electron emission is performed in a mottled pattern. Accordingly, there arises a drawback ⁱⁿ that it is difficult to always obtain ^a ~~the~~ uniform electron emission from the whole surface of the electron source. There also arises a drawback ⁱⁿ that ~~an~~ ^{the} electron emission quantity per se becomes insufficient. When the electron emission quantity becomes insufficient and non-uniform, the brightness of a video screen also becomes insufficient, and, hence, it is difficult to ensure ^{a desirable} ~~the~~ display quality. Accordingly, there arise drawbacks ^a ~~such as a drawback~~ ⁱⁿ that it is difficult to obtain ~~the~~ high quality display and ^a ~~a~~ drawback ⁱⁿ that the exhaustion of the electron source is accelerated, thus impeding the acquisition of ^a ~~the~~ long lifetime ^{of use}. These drawbacks constitute ^{problems} ~~tasks~~ to be solved by the present invention.

[0015]

Accordingly, it is an object of the present invention to provide a display device ^{that is} ~~capable of~~ ^{producing} a desired high-quality display and ^{which has} ~~having~~ ^{of use} a long lifetime, by solving the above-mentioned various drawbacks.

[0016]

To achieve the above-mentioned object, the representative constitution of the present invention is characterized by ~~the~~ ^{an} improvement of the structure which connects cathode lines and electron sources. Hereinafter, ~~the~~ representative constitutions of the display device of the present invention ~~are~~ ^{will be} described.

~~100171~~

That is, the display device according to the present invention comprises a face substrate which ~~forms~~ ^{has} anodes and phosphors ^{formed} on an inner surface thereof, a plurality of cathode lines which extend in one direction and are arranged in parallel in another direction which ~~crosses~~ ^{the} one direction and ^{which} have electron sources ^{thereon}, control electrodes which face the cathode lines in a display region and have electron passing apertures for allowing electrons from the electron sources to pass through the electron passing apertures to the face substrate side, a back substrate which ~~forms~~ ^{has} the control electrodes and the cathode lines ^{formed} on an inner surface thereof and faces the face substrate in an opposed manner with a given distance therebetween, a support body which is interposed between the face substrate and the back substrate in a state ^{such} that the support body surrounds the display region and ^{maintains} ~~holds~~ the given distance ^{therebetween}, and a sealing material which hermetically seals end faces of the support body and the face substrate and the back substrate, respectively, wherein a connecting portion of the cathode line

with the electron source has a composition which includes a conductor and an insulator, and ^{the} ~~an~~ occupancy rate of the conductor in the composition is set ^{to be} ~~equal~~ to or more than ^{the} ~~an~~ occupancy rate of the insulator in the composition.

~~[0018]~~

Further, the display device according to the present invention may be constituted such that the occupancy rate of the insulator is less than 50% and a surface of the back substrate in the vicinity of the cathode lines exhibits an uneven shape.

~~[0019]~~

That is, the display device according to the present invention comprises a face substrate which ^{has} ~~forms~~ anodes and phosphors ^{formed} on an inner surface thereof, a plurality of cathode lines which extend in one direction and are arranged in parallel in another direction which crosses ^{the} ~~one~~ direction and ^{which} ~~have~~ electron sources ^{thereon}, control electrodes which face the cathode lines in a display region and have electron passing apertures for allowing electrons from the electron sources to pass through the electron passing apertures to the face substrate side, a back substrate which ^{has} ~~forms~~ the control electrodes and the cathode lines ^{formed} on an inner surface thereof and faces the face substrate in an opposed manner with a given distance therebetween, a support body which is interposed between the face substrate and the back substrate in a state ^{such} ~~that~~ the support

body surrounds the display region and ^{maintains a} ~~holds the~~ ^{distance} ~~the~~ given distance, and a sealing material which hermetically seals end faces of the support body and the face substrate and the back substrate, respectively, wherein a layer having a high conductor occupancy rate is interposed in a connecting portion between the cathode line and the electron source.

~~[0020]~~

Further, the display device according to the present invention may be constituted such that the layer in which the conductor has ^a ~~the~~ high occupancy rate is a silver particle layer or a gold particle layer.

~~[0021]~~

Due to the above-mentioned constitutions, it is possible to provide ^a ~~the~~ display device which can ^{produce a} ~~perform the~~ high quality display and can have ^a ~~the~~ long lifetime ^{of use}.

~~[0022]~~

Here, the present invention is not limited to the above-mentioned constitution and ^{to} ~~the~~ constitution of embodiments described later, and various modifications can be made without departing from the technical concept of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

~~Fig. 1A and Fig. 1B are explanatory views of the schematic constitution showing one embodiment of a display device~~

~~according to the present invention, wherein Fig. 1A is a~~
~~one embodiment of a display device according to the present invention,~~
schematic plan view^(a) as viewed from a face substrate side, and
Fig. 1B^(b) is a schematic side view as viewed from the direction
indicated by an arrow A in Fig. 1A^(a);

~~Fig. 2A and Fig. 2B are explanatory views of a~~
~~constitutional example of a back substrate of the display device~~
~~shown in Fig. 1A and Fig. 1B, wherein Fig. 2A~~^(a)
~~of the back substrate of the display device of Fig. 1A~~
plan view^(a) as viewed from above in the z direction, and Fig. 2B^(b)
is a schematic side view as viewed from the direction indicated
by an arrow B in Fig. 2A^(a);

Fig. 3 is a schematic perspective view showing an
essential part of one embodiment of the display device according
to the present invention shown in Fig. 1A^(a) and Fig. 1B^(b), as well
as in Fig. 2A^(a) and Fig. 2B^(b) in an enlarged manner;

Fig. 4 is a schematic cross-sectional view showing an
essential part in Fig. 3;

Fig. 5 is a schematic cross-sectional view showing an
essential part in Fig. 4 in an enlarged manner;

Fig. 6 is a schematic cross-sectional view of another
embodiment of the display device according to the present
invention and corresponds to Fig. 5;

Fig. 7 is a schematic cross-sectional view further
showing an essential part of another embodiment of the display
device according to the present invention in an enlarged form;

Fig. 8 is a ~~view~~^{graph} showing the relationship between the

property and the light emitting uniformity of a connecting
portion of a cathode line ~~to explain~~ ^{as it relates to} the present invention;

Fig. 9 is a SEM photograph showing a surface of the cathode
line ~~to explain~~ ^{as it relates to} the present invention;

Fig. 10 is a SEM photograph showing a surface of one
example of the cathode line used in the display device of the
present invention;

Fig. 11 is a SEM photograph showing a surface of another
example of the cathode line used in the display device of the
present invention;

Fig. 12 is ~~an explanatory view~~ ^{a diagram showing} of an example of an
equivalent circuit of the display device according to the
present invention;

Fig. 13 is a schematic ~~view for explaining~~ ^{diagram showing} the basic
constitution of a field emission type display;

Fig. 14 is a schematic cross-sectional view ~~for~~
~~explaining~~ ^{showing} a constitutional example of a field emission type
display; and

Fig. 15 is a schematic plan view of a field emission type
display ^{as} shown in Fig. 14.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

~~10023~~

Preferred embodiments of the present invention ^{will be} ~~are~~
^{the} explained in detail hereinafter in conjunction with ^{the} drawings.

~~which show these embodiments. Fig. 1A and Fig. 1B are explanatory views of the schematic constitution of a field emission type display device showing one embodiment of a display device according to the present invention, wherein Fig. 1A is a plan view as viewed from a face substrate side, Fig. 1B is a side view as viewed from the direction indicated by an arrow A in Fig. 1A. Fig. 2A and Fig. 2B are schematic explanatory views of a constitutional example of a back substrate constituting the display device shown in Fig. 1A and Fig. 1B, wherein Fig. 2A is a plan view as viewed from above in the z direction and Fig. 2B is a side view as viewed from the direction indicated by an arrow B in Fig. 2A.~~

~~[0024]~~

In Fig. 1^(a)_A and Fig. 1^(b)_B as well as in Fig. 2^(a)_A and Fig. 2^(b)_B, numeral 1 indicates a back substrate, numeral 2 indicates a face substrate, numeral 3 indicates a support body which also functions as an outer frame, and numeral 4 indicates an exhaust pipe (in a sealed state). Further, numeral 5 indicates cathode lines, numeral 6 indicates control electrodes, numeral 7 indicates electrode pressing members, and numeral 8 indicates an exhaust port, wherein the exhaust port 8 is formed in the back substrate 1 and is in communication ~~communicated~~ with the exhaust pipe 4. Here, the exhaust pipe 4 is shown in a pre-sealed state in Fig. 1^(b)_B. The back substrate 1 ^{is} ~~is~~ constituted ^{by} ~~of~~ an insulation substrate which is preferably made of glass or ceramic such as

alumina in the same manner as the face substrate 2 and has a film thickness of several mm, for example, 3mm. The face substrate 2 and the back substrate 1 are stacked in the z direction. Here, the z direction indicates a direction which is orthogonal to ^{the} substrate surfaces of the back substrate 1 and the face substrate 2. On an inner surface of the back substrate 1, a plurality of cathode lines 5, having ^a ~~the~~ constitution ^{to be} described later, extend in one direction (the x direction) and are arranged in parallel in another direction (the y direction). End portions of the cathode lines 5 are pulled out to the outside of the support body 3 as lead lines 5a of the cathode lines 5.

~~100-15~~ ^{These}
Above the cathode lines 5, ^{the} control electrodes 6, which are formed of a plurality of strip-like electrode elements 61 ^{which} ~~are arranged, wherein the plurality of~~ strip-like electrode elements 61 are insulated from the cathode lines 5, extend in the y direction and are arranged in parallel in the x direction. Further, at ^{the} ~~an~~ outer periphery of ^{the} ~~a~~ gap defined between opposing surfaces of the back substrate 1 and the face substrate 2, the support body 3 is interposed. A sealing material is interposed between both end surfaces of the support body 3 and both substrates 1, 2 thus hermetically sealing ^{the} ~~an~~ inside ^{space defined} ~~surrounded~~ by the support body 3 and both substrates 1, 2. Then, by evacuating the inside through the exhaust pipe 4, a given degree of vacuum is created in the ^{space} ~~inside~~. The above-mentioned

hermetic sealing is performed ^{sealing} ~~such that~~ the inside ^{space} ~~is heated~~ in a nitrogen atmosphere, for example, at a temperature of approximately 430°C, for example, and thereafter, the inside ^{space} is evacuated while being heated at a temperature of approximately 350°C, for example, thus sealing the inside ^{space} in a vacuum state.

~~[0026]~~

Here, as the sealing material, for example, a glass material which has the composition of 75 to 80 wt% of PbO, approximately 10 wt% of B₂O₃, and 10 to 15 wt% of balance and contains amorphous type frit glass can be preferably used.

~~[0027]~~

Further, unit pixels are formed on crossing portions of the cathode lines 5 and the control electrodes 6 in a matrix array, and the above-mentioned display region is formed of these pixels arranged in the matrix array. In general, ~~the above-mentioned~~ three unit pixels form a group and constitute a color pixel consisting of red (R), green (G) and blue (B) ^{colors}.

~~[0028]~~

Here, the control electrodes 6 are constituted by arranging a large number of strip-like electrode elements (metal ribbons) 61 having electron passing holes in parallel and ^{have been} ~~are~~ proposed by ^{the} inventors of the present invention in the course of development arriving at the present invention.

~~[0029]~~

The control electrodes 6 may be manufactured in a separate step as separate parts. The control electrodes 6 are arranged above (the face substrate 2 side) and close to the cathode lines 5, which have electron sources ^{thereon}, and, at the same time, ~~have~~ ^{are} portions thereof in the vicinity of both end portions thereof fixed to the back substrate 1 by the electrode pressing members 7 or the like, which are arranged outside a display region AR and inside the support body 3 and are made of an insulator, such as a glass material or the like. Further, the lead lines 62 are connected to the control electrodes 6 in the vicinity of the electrode pressing members 7 or in the vicinity of the support body 3, and these lead lines 62 ^{extend} ~~are pulled~~ out to an outer periphery of the display device and are connected to external circuits. The lead lines 62 may be formed by directly extending the strip-like electrode elements 61.

~~[0030]~~ ^{Using the}
~~The~~ control electrodes 6 having such a constitution ~~can~~, ^{as} compared to the structure in which control electrodes are formed by forming metal thin films on an insulation layer by vapor deposition, ^{it is easy to} ~~uniform~~ ^{uniform} set a gap ~~defined~~ between the control electrodes and the cathode lines 5 ~~uniform~~, and, hence, the control characteristics of respective pixels can be made uniform over the whole area of the display region, thus enabling the acquisition of ^a ~~the~~ high quality video display.

~~[0031]~~

~~FIG. 3~~ Fig. 3 is a schematic perspective view showing an essential part of a field emission type display device which ^{represents} ~~is~~ one embodiment of the display device according to the present invention, ^{as} shown in Fig. 1^(a)~~A~~ and Fig. 1^(b)~~B~~, as well as in Fig. 2^(a)~~A~~ and Fig. 2^(b)~~B~~, in an enlarged form, while Fig. 4 is a schematic cross-sectional view showing an essential part in Fig. 3, ^{and} ~~shows a vertical cross section in the direction (the y direction) orthogonal to the extending direction (the x direction) of the cathode lines 5 in Fig. 3. Numerals in Fig. 3 and Fig. 4 equal to the numerals used in Fig. 1A and Fig. 1B as well as in Fig. 2A and Fig. 2B indicate identical functional portions.~~ In Fig. 3 and Fig. 4, the formation of the cathode lines 5 may ^{be effected} ~~be effected~~ either ^{by} ~~one of~~ a method which forms the cathode lines 5 by a vacuum thin film forming process, as represented by a vapor deposition method or a sputtering method, ^{or by} ~~and~~ a thick wall printing process, ⁱⁿ ~~which~~ ^{are formed} ~~forms~~ the cathode lines 5, by printing and baking a metal paste having ^a ~~the~~ constitution which contains approximately several % to 20% of metal particles and a low-melting-point glass component. In this embodiment, the latter method is adopted.

~~[0032]~~

That is, the cathode lines 5 are formed by printing a silver paste having a large thickness and, thereafter, by baking the printed silver paste at a temperature of 60°C, for example. Here, the silver paste is formed by mixing a low melting-point

glass which exhibits ~~the~~^{an} insulation property into conductive silver particles having a particle size of several μm , that is, approximately 1 to $5\mu\text{m}$, for example.

~~[0033]~~

On the other hand, on the cathode lines 5, electron sources 51, which are formed of a diamond film, a graphite film, carbon nanotubes or the like, are formed at a given pitch. The details of ~~the~~^{the} connection between the electron sources 51 and the cathode lines 5 ~~is~~^{will be} explained ~~in detail~~ in conjunction with Fig. 5 and succeeding drawings later.

~~[0034]~~

Further, above the cathode lines 5 (the face substrate 2 side) ~~the~~^{an} the control electrodes 6, which are constituted by ~~arranging~~ a large number of strip-like electrode elements 61 having a plurality of electron passing apertures ~~6a~~^{which} are arranged close to the cathode lines 5. For example, the control electrodes 6 are arranged close to the cathode lines 5 such that ~~the~~^{the} gap between the electron sources 51 and the electron passing apertures 6a is set to approximately 0.1mm or less. The cathode lines 5 and the control electrodes 6 face each other in an opposed manner at least over the whole area of the display region AR and ~~the~~^{electrical} insulation is ensured between the cathode lines 5 and the control electrodes 6. Further, numeral 6b indicates projecting portions formed on the strip-like electrode element 61.

~~0035~~

In this embodiment, each electron passing aperture 6a formed in the strip-like electrode element 61 is constituted of a ~~mass of a~~ large number of small electron passing apertures 6an. Further, ^{the} distal ends of the projecting portions 6b are formed of a sealing material 10, ^{that is} which is of a type, substantially ^{the same as} ~~equal to~~ the sealing material used for the previously-mentioned hermetic sealing between the support body 3 and both substrates 1, 2, ^{they} and are fixed to an inner surface of the back substrate 1. This fixing can be performed in ^a ~~the~~ nitrogen atmosphere, for example, at a temperature of 450°C, for example.

~~0036~~

The control electrodes 6 ~~described~~ in this embodiment, which are constituted by arranging a large number of strip-like electrode elements 61 in parallel, ^{have been} are electrodes which ~~are~~ proposed by the inventors of the present invention in the course of development arriving at the present invention. Here, these strip-like electrode terminals 61 are formed of an iron-based stainless steel material or an iron material and have a plate thickness of approximately 0.025mm to 0.150mm, for example. The control electrodes 6 are constituted by extending the strip-like electrode elements 61 in the y direction and arranging the strip-like electrode elements 61 in parallel in the x direction.

~~0037~~

Further, at the crossing portions of the cathode lines 5 and the plate-like control electrodes 6, the electron sources 51 and the electron passing apertures 6a are arranged to face each other in an opposed manner.

~~10038~~

In such a constitution, electrons emitted from the electron sources 51, ~~that are~~ ^{are subjected to} arranged on the cathode lines 5 ~~receive a~~ control in the electron passing apertures 6a of the control electrodes 6, to which a grid voltage of approximately 100V is applied, and, thereafter, ~~they~~ ^{they} pass through the electron passing apertures 6a. Then, the electrons advance toward a phosphor screen 20 to which an anode voltage of several KV to 10 and some KV is applied, and, ~~they~~ ^{that is} penetrate a metal back film 21 (anode) which constitutes the phosphor screen 20, arranged on the face substrate 2 and impinge on a phosphor film 22, thus making the phosphor film 22 emit light, whereby a desired display is performed on a video image screen. Here, although not shown in the drawing, the phosphor screen 20 includes black matrix films (BM), and hence, the phosphor screen 20 of this embodiment has ^a ~~the~~ constitution, ^{which is} ~~substantially equal to~~ ^{the same as} the constitution of ^{the} ~~a~~ phosphor screen of a conventional color cathode ray tube.

~~10039~~

Next, the connecting structure between the cathode lines 5 and the electron sources 51, ^{as will be} which are formed on the cathode lines 5, ~~is~~ explained in conjunction with Fig. 5. That is, Fig.

5 is a schematic cross-sectional view showing an essential part of the cathode line, the electron source and the like shown in Fig. 4 in an enlarged manner. The cathode line 5 has ~~the~~^a composition in which the property of a connecting portion 5b connected with the electron source 51 is set such that ~~the~~^{the} conductor occupancy rate becomes equal to or more than ~~an~~^{an} insulator occupancy rate.

~~{0040}~~

To explain this composition of the cathode line 5 in ^{more} detail, as mentioned previously, the cathode line 5 is formed of ~~the~~ silver paste, which is produced by mixing ~~the~~ low melting-point glass, which exhibits ^{an} ~~the~~ insulation property, into ~~the~~ conductive silver particles having a particle size of several μm , that is, approximately 1 to $5\mu\text{m}$, for example. This silver paste is printed and baked on the back substrate 1 by a thick film printing process, wherein a thick film is formed by baking the silver paste at a temperature of 600°C , for example. Then, a surface of the thick film which constitutes a contact portion 5b with the electron source 51 is etched by chemical etching so as to remove portions or the whole of ^{the} ~~the~~ glass component in the surface, whereby the conductor occupancy rate of the connecting portion 5b becomes equal to or more than the insulator occupancy rate thereof. A carbon nanotube paste is printed on a surface of the connecting portion 5b having such a property, and the paste is baked at a temperature of 590°C in

a vacuum, for example, thus forming the electron source 51.

~~FIG. 5~~

In this embodiment, as the carbon nanotube paste, a paste which is produced by dispersing single-wall carbon nanotubes into ethylene cellulose and terpineol is used. Although the ^{of this embodiment} ~~limited~~ explanation, is ~~made with respect~~, to a case which uses the single-wall carbon nanotubes ~~in the above description~~, multi-wall carbon nanotubes or carbon nanofibers may be used in place of the single-wall carbon nanotubes. Further, besides the above-mentioned materials, diamond, diamond-like carbon, graphite, amorphous carbon or the like can be used. Still further, it is needless to say that ^a ~~the~~ mixture of these materials can be also used. It is also needless to say that the electron source may contain metal particles, such as silver particles or the like, or a quantity of insulating material which does not impede the emission of electrons.

~~FIG. 6~~

By adopting the constitution shown in Fig. 5, in the connecting portion 5b, as described above, the glass component between the silver particles ^{is} ~~are~~ removed and the conductor is exposed over ^{the} ~~the~~ substantially ^{the} whole surface. Accordingly, the conduction between the cathode lines and the electron sources is enhanced such that the conduction is carried out over ^{the} ~~the~~ substantially ^{the} whole surface of the connecting portions, thus enabling the electron emission from ~~the~~ ^{the} substantially ^{the} whole

surface of the electron sources, and, at the same time, it is possible to obtain ~~the~~^a uniform emission quantity for a long ^{of time} period.

~~10043~~

In the constitution shown in Fig. 5, the phosphor screen ^{so as to be spaced} 20 is arranged away from the electron sources 51 by 300 μ m in a vacuum and the connection structure is operated by applying a voltage of approximately 900V to the phosphor screen 20. As ^a ~~the~~ result of such ~~an~~ operation, ^a ~~the~~ substantially uniform light emission is obtained, and the non-uniform light emission in a mottled pattern is not observed.

~~10044~~

Here, in the cathode line 5, the glass component is removed only from the connecting portion which contributes to the connection of the cathode line 5 with the electron source 51 and a desired quantity of glass component is mixed into a portion of the cathode line ⁵ ~~is~~ disposed below the connecting portion, and, hence, the film per se holds ^{the} ~~the~~ sufficient rigidity, and there is no possibility that ~~an~~ ^{the} adhesive strength between the cathode line 5 and the back substrate 1 is lowered.

~~10045~~

When the display device, on which the back substrate 1 having the connecting structure shown in Fig. 5 is mounted, is operated with ^{an} ~~the~~ anode voltage of 7kV and ^a ~~the~~ grid (control electrode) voltage of 100V (60Hz driving), all pixels emit ^a ~~the~~

substantially uniform light and exhibit ~~the~~^a sufficient brightness necessary ~~as~~^{to produce} a display, and, hence, it is confirmed that the display device can be practically used.

~~{0046}~~

Fig. 6 is a schematic cross-sectional view showing an essential part of another embodiment of the display device according to the present invention in an enlarged form and corresponds to Fig. 5. In Fig. 6, numeral 50 indicates a cathode line and numeral 52 indicates a conductor layer. The conductor layer 52 is obtained by applying a paste in which fine silver particles having a particle size of approximately 10nm, for example, are dispersed to the cathode line 50, and by baking the applied paste at a temperature of 350°C, for example. Thus, the conductor layer 52 is formed of only fine silver particles. The use of the fine silver particles is characterized ^{by the fact} ~~in~~ that the fine silver particles can be sintered by baking at a temperature of at least approximately 300°C, for example, even when a glass component is not contained in the paste. The silver particle layer may be replaced by a fine particle paste which is formed by using ^{another} ~~other~~ metal, such as a fine particle paste made of gold, for example. Further, in the same manner ^{described with reference to} as Fig. 5, a carbon nanotube paste is applied to a surface of the conductor layer 52, and the paste is baked at a temperature of 590°C in a vacuum, thus forming an electron source 51.

~~{0047}~~

On the other hand, the cathode line 50 is formed of the same material as the above-mentioned cathode line 5 and is formed by printing and baking the material. However, the chemical etching treatment is not performed. By interposing the above-mentioned conductor layer 52 between the cathode line 50 and the electron source 51, ^{the} ~~the~~ substantially ^{the} whole surface of the electron source 51 at the cathode line 50 side is brought into contact with the conductor. Accordingly, it is confirmed that ~~the~~ ^{the} electron emission can be realized from ~~the~~ substantially ^{the} whole surface of the electron source 51, and, at the same time, a uniform emission quantity of electrons can be obtained for a long time.

~~[0048]~~

That is, in the constitution shown in Fig. 6, the phosphor screen 20 is arranged ^{so as to be spaced} away from the electron sources 51 by 300 μ m in a vacuum and the connection structure is operated by applying a voltage of approximately 900V to the phosphor screen 20. As ^a ~~the~~ result of such an operation, ^a ~~the~~ substantially uniform light emission is obtained, and ^a ~~the~~ non-uniform light emission in a mottled pattern is not observed, and, hence, the advantageous effect of the present invention is ^{attained} ~~achieved~~.

~~[0049]~~

On the other hand, the above-mentioned glass component exists in a connecting portion between the conductor layer 52 and the cathode line 50. However, provided that the conduction

between them is ensured at some portions of the connecting portion, the function can be achieved, and, hence, the interposition of the glass component does not cause any problem. Further, the cathode line 50 per se is formed of ~~the~~ silver paste, which mixes ~~the~~ low melting-point glass which exhibits ^{an} ~~the~~ insulating property into the conductive silver particles as mentioned previously. Accordingly, compared to a case in which both films formed of the cathode line 50 and the conductor layer 52 are integrally formed of only the above-mentioned fine silver particles, it is possible to manufacture the connecting structure at a low cost, and, at the same time, there is no possibility that the adhesive strength between the cathode line 50 and the back substrate 1 is lowered.

~~100507~~

Here, it is needless to say that another conductor layer may be interposed between the cathode line 50 and the conductor layer 52 or between the cathode line 50 and the back substrate 1.

Further, although ^{an} ~~the~~ explanation ^{has been} ~~is~~ made with respect to ^a ~~the~~ case in which the cathode line is formed of ~~the~~ silver paste ~~heretofore~~, it is needless to say that the cathode line ^{may be} ~~is~~ formed by using other metal particles, such as gold particles, nickel particles or the like, for example. Further, although a non-photosensitive paste is used as the silver paste, a photosensitive paste may be used as the silver paste. Still

further, it is needless to say that the present invention is also applicable to ^a~~the~~ constitution, which ^{is} ~~obtains~~ the cathode line and the electron sources ^{are produced} by patterning using a photolithography process.

~~[0051]~~

~~FIG. 7~~ Fig. 7 is a schematic cross-sectional view showing ^{a representative} ~~an essential~~ part of another embodiment of the display device according to the present invention in an enlarged form. In the drawing, ~~numerals equal to~~ ^{same as those} the numerals used in Fig. 1 to Fig. 6 indicate ~~the~~ identical functional portions. In Fig. 7, numeral 1a indicates an inner surface of a back substrate 1, and ^{this} ~~the~~ inner surface 1a exhibits an uneven shape. That is, the uneven shape is formed by removing ~~the~~ portions of the glass component on the surface simultaneously when the chemical etching treatment is applied to the glass component in the connecting portion 5b of the cathode line ^{as} 5, explained in conjunction with Fig. 5. In this manner, by forming the uneven shape on the inner surface 1a of the back substrate 1, in addition to the advantageous effect explained in conjunction with Fig. 5, it is possible to increase the mutual creeping distance between the neighboring electrodes, whereby ^{an} ~~the~~ enhancement of the dielectric strength can be achieved.

~~[0052]~~

Here, it is needless to say that the uneven shape may be formed before applying the cathode lines 5 on the inner surface

la of the back substrate 1, ^{it} or may be formed by a known processing method other than ~~the~~ chemical etching. Further, by preliminarily forming the whole surface of the inner surface la of the back substrate 1 into ^{an} ~~the~~ uneven shape and, thereafter, by forming the cathode lines 5 and the like, it is possible to obtain an advantageous effect, ⁱⁿ that the adhesive strength for adhering the inner surface la of the back substrate 1 with the electrodes to be mounted on the inner surface la can be further enhanced.

~~[0053]~~

~~Figure~~ Fig. 8 is a ^{graph} ~~view~~ showing the relationship between the property and the light emitting uniformity of the connecting portion of the cathode line of one embodiment of the display device according to the present invention. In the drawing, ^{the} ~~a~~ glass occupancy rate (area ratio) G_a (%) in the composition of the connecting portion of the cathode line is taken on an axis of abscissas and ^{the} ~~an~~ electron emission site density E_d (pieces/mm²), which becomes an index of the light emission uniformity, is taken on an axis of ordinates.

~~[0054]~~

In Fig. 8, first of all, the cathode lines are formed using the above-mentioned silver paste which is usually used, that is, ^a ~~the~~ silver paste which contains ~~the~~ silver particles and ~~the~~ low melting-temperature glass is formed. The glass occupancy rate (area ratio) G_a (%) of the connecting portion

of the cathode line is 80%. Subsequently, the glass component is gradually expelled from the surface which constitutes the connecting portion of the cathode line with the electron source, and, then, ^{an} ~~the~~ electron source is formed on the surface. Thereafter, the electron emission site density E_d with respect to the glass occupancy rate G_a is measured. The expulsion of the glass component is performed by the removal of silver oxide on the surface of the silver particles in a lift-off manner.

~~[0055]~~

That is, the surface of the cathode line which is formed by printing and baking the silver paste has, as indicated in ~~the~~ SEM photograph shown in Fig. 9, ^a ~~the~~ constitution in which the melted glass surrounds ^{the} peripheries of silver particles or lead particles in the low melting-temperature glass. The cathode line having such a surface condition is treated in a lift-off manner as described above to expel the glass component using thiourea system chemicals (for example, ESCREEN AG-301, a product of Sasaki Kagaku Yakuhin Kabushiki Kaisha). Fig. 10 is a SEM photograph showing the surface of the cathode line after the treatment. As can be understood from the SEM photograph, in the surface which constitutes the connecting portion, only the glass component between the silver particles is removed.

~~[0056]~~

Next, the measurement of the electron emission site density is performed by an emission profiler having minute

apertures in a measuring anode (for example, a product of Tokyo Cathode Ltd.) under conditions where ~~an~~^{the} aperture diameter is set to $10\mu\text{m}$, ~~a~~^{the} distance between the anode and an electron source is set to $50\mu\text{m}$, and ~~a~~^{the} measuring step is set to $10\mu\text{m}$. As can be understood from Fig. 8, it ~~is~~^{was} found that when the glass occupancy rate G_a is lowered to a value below 50% as ~~the~~^a result of the gradual expulsion of the glass component from the surface which constitutes the connecting portion 5b of the cathode line 5 with the electron source 51, the light emitting brightness can obtain ~~the~~^a practically sufficient electron emission site density. Although the electron emission site density rapidly changes when the glass occupancy rate is in a range of 70% to 50%, there exists a possibility that the light emitting brightness ~~will~~^{will} become insufficient when the glass occupancy rate is 60%. Accordingly, it is important from a practical point of view that the glass occupancy rate is below 50%.

~~100571~~

On the other hand, when the glass occupancy rate is 50% or below, as shown in the drawing, it is possible to ensure ~~the~~^a sufficient electron emission site density. However, even when the glass occupancy rate ~~is~~^{at} 50% is lowered to approximately 10%, the difference in the electron emission site density between the case in which the glass occupancy rate is 50% and the case in which the glass occupancy rate is 10% is extremely small, and, hence, the glass occupancy rate may be determined

based on the balance between a treatment operation amount for expelling the glass component and the electron emission site density.

~~[0058]~~

~~Figure~~ Fig. 11 is a SEM photograph showing a surface of the conductor layer 52 which is interposed between the cathode line 50 and the electron source 51 having the constitution shown in Fig. 6 and ^{which} has the whole thereof formed of only fine silver particles. To compare the surface state indicated in Fig. 11 and the previously-mentioned surface state indicated in Fig. 9, the difference is evident. That is, it is possible to confirm ^{the} with naked eye that the surface of the conductor layer 52 is covered with a silver film which hardly contains the glass component. Accordingly, by merely applying the electron source 51, such as carbon nanotubes, for example, to the cathode line without affording any treatment to the surface of the conductor layer 52, ^a ~~the~~ substantially uniform electron emission ^{produced} can be ~~performed~~ from the whole surface of the electron sources, and, hence, ^a ~~the~~ desired display is obtained.

~~[0059]~~

~~Figure~~ Fig. 12 is an ~~explanatory view of an example of an~~ ^{diagram} equivalent circuit of the display device of the present invention. ^{the} ~~a~~ region indicated by a broken line in the drawing indicates a display region AR. In the display region AR, the cathode lines 5 and the control electrodes 6 (strip-like

electrode elements 61) are arranged to cross each other thus forming a matrix of $n \times m$ ^{lines}. Respective crossing portions of the matrix constitute unit pixels, and one color pixel is constituted of a group of "R", "G", "B" ^{unit pixels} in the drawing. The cathode lines 5 are connected to a video drive circuit 200 through the cathode line lead lines 5a (X1, X2, ... Xn), while the control electrodes 6 are connected to a scanning drive circuit 400 through control electrode lead lines 62 (Y1, Y2, ... Ym). The video signals 201 are inputted to the video drive circuit 200 from an external signal source, while scanning signals (synchronous signals) 401 are inputted to the scanning drive circuit 400 in the same manner.

~~100601~~

Accordingly, the ~~given~~ pixels which are sequentially selected by the strip-like electrode elements 61 and the cathode lines 5 are illuminated with lights of given colors so as to display a two-dimensional image. With the provision of the display device having such a constitution ^{for} ~~an~~ example, it is possible to realize a flat panel type display device which is operated by a relatively low voltage and, hence, exhibits ^a high efficiency.

~~100611~~

As has been explained heretofore, by constituting the connecting portion of the cathode line with the electron source such that the conductor occupancy rate becomes equal to or more

than the insulator occupancy rate, ~~the~~ electron emission from the whole surface of the electron source can be ^{produced} ~~performed~~ and, at the same time, ^a ~~the~~ uniform emission quantity can be obtained for a long time, whereby it is possible to provide ^a ~~the~~ display device which can ^{produce a} ~~perform the~~ high quality display and ^{which} has a long lifetime.

~~#00631~~

Further, by interposing the layer in which the conductor exhibits ^a ~~the~~ high occupancy rate in the connecting portion between the cathode line and the electron source, ~~the~~ electron emission from the whole surface of the electron source can be ^{produced} ~~performed~~ and, at the same time, ^a ~~the~~ uniform emission quantity can be obtained for a long time. Further, the adhesive strength between the back substrate and the cathode line can be sufficiently ensured, whereby it is possible to provide ^a ~~the~~ display device which is capable of exhibiting ^a ~~the~~ high quality display and ^{which} has a long lifetime.